

Application No. 10/717,268
Amendment dated May 10, 2006
Reply to Office Action of February 10, 2006

Amendments to the Specification:

Please replace paragraph [0067] with the following amended paragraph:

[0067] High-density inductively coupled plasmas have produced processing effects that are greater at the center of the wafers 15 than toward the wafer edges. Applicant has proposed to improve uniformity with a ring-shaped plasma in U.S. Patent No. 6,534,4936,523,493, hereby expressly incorporated by reference herein. In that patent, the use of a permanent magnet to shape the plasma was proposed. With the present invention, shaping of a plasma is provided by use of a locally-efficient RF ICP source. Such a source uses, for example, a series or arrangement of locally-efficient plasma generation, for example, by generating concentrations of plasma energy in a ring within the vacuum processing chamber. In the described embodiments, this local coupling efficiency is achieved by various embodiments of locally-efficient antenna structure, locally transparent shield structure, and combinations of antenna and shield structure. The shaped plasma is achieved in certain of the described embodiments by providing such locally-efficient structure in a peripheral ionization source in semiconductor wafer etching and coating processes and systems.

Please replace paragraphs [0073], [0074] and [0075] with the following amended paragraphs:

[0073] A feature of the segmented antenna element [[50]] 40 is that its total inductance is lower than for a non-segmented antenna, such as antenna 26a or 26b, thereby making it technically more suitable for large area plasma processing systems, such as for 300 mm wafers 15, while maintaining the simplicity typical of smaller size ICP sources. The segmented antenna 40 is provided with an azimuthally modulated pitch that provides a spatial distribution of the rf power deposited into plasma, reduced ohmic losses in the deposition shield 50, low-inductance, and locally enhanced RF power density distribution 60a, 60b into plasma. The spatial RF power density distribution 60a, 60b allows for the design of a deposition shield 50 with enhanced shielding performance.

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[0074] Design of the conductors of the segmented antenna or antennas 40 may be understood by reference to **Fig. 3**. An antenna 40 may be formed of a serial conductor 43, through ~~which may~~ which current may be considered as instantaneously flowing in a direction indicated by arrows 44, that consists of the serial connection of two sizes of conductors or conductor sectors 45 and 46, each with respectively different cross-sections S_1 and S_2 in a direction perpendicular to the current flow 44. Each of the different cross-section conductor sectors 45 and 46 has a length defined as L_1 and L_2 , respectively, in a direction parallel to the current flow 44. Accordingly, the conductor 43 may be described as having a “filling factor”, Φ , which is defined as a ratio of a conductor length L_2 , related to a large cross-section portion 46 to a total conductor length L_1 and L_2 , (sum of conductor lengths both for small and large cross-section portions 45 and 46), e.g. $\Phi = L_2 / (L_1 + L_2)$. The conductor may also be defined in part by the “cross-section ratio”, Θ , as the ratio of the cross-sectional area S_2 of the large cross-section segment 46 to the area S_1 of the small cross-section segment 45, or $\Theta = S_2 / S_1$.

[0075] A constant RF current flows through the conductor 43. At the RF frequencies used, this current flows close to the surface of the conductor 43 in the manner that it would flow through a cage of wires surrounding a space of the solid conductor’s cross-section. In the case of the smaller cross-section segment 45, the surface current density is significantly higher than in the case of the larger cross-section segment 46. Consequently, the induced RF magnetic fields H_1 are stronger in the immediate vicinity of the surface of conductor segment 45 than the fields H_2 in the vicinity of the surface of conductor 46, and thus stronger inductive coupling will occur, and larger currents I_1 will be induced, within the plasma adjacent conductor segment 45 than currents I_2 ~~induced adjacent~~ induced into adjacent segment 46. RF power 61b, 61a coupled into the plasma adjacent segments 45 will in turn be larger than the RF power 62a, 62b coupled adjacent segments 46 (Fig. 2O and 2F).

Please replace paragraphs [0078] and [0079] with the following amended paragraphs:

[0078] **Fig. 4** is a cut-away perspective view of the material source 20 of **Fig. 1** equipped with a peripheral inductive element for generating ICP in accordance with an embodiment of the

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invention. The element includes a three-dimensional segmented antenna 40 on the outside of a planar window 25 with a correspondingly segmented deposition baffle or shield 50 protecting the inside of the window 25. Such an element may be that, for example, illustrated in **Fig. 2D** **Fig. 2E**, producing a plasma power distribution as illustrated in **Fig. 2E** **Fig. 2D**, which is illustrated in more detail as element 40a in Fig. 4A.

[0079] In **Fig. 4A**, the antenna 40a is depicted adjacent dielectric window 25. Baffle 50a is located on the opposite side of the window 25 from the antenna 40a. The antenna 40a is shown as formed of a continuous conductor 43a having four concentric loops 47a of six segments each when viewed from the top. A spiral band or a series of rings (not shown) of insulating material, for example of TEFLON, may be interposed between adjacent pairs of the windings 43a or others of the windings 43 in other embodiments. Each winding 47a has six small cross-section conductor segments 45a alternating with six large cross-section conductor segments 46a, with the segments 45a,46a of each winding aligning with similar segments of the adjacent winding 47a. The small cross-section windings 45a aligning radially to form radial wedge-shaped high-radiation efficiency portions 41a of the antenna 40a and the large cross-sections [[45a]] 46a aligning radially to form radial wedge-shaped low-radiation efficiency portions 42a of the antenna 40a.

Please replace paragraph [0084] with the following amended paragraph:

[0084] **Fig. 5** illustrates a peripheral inductive element of a type suitable for an ICP etch module such as the etch apparatus 30 of **Fig. 1A**. In such an apparatus, the quartz chamber bell jar-shaped wall 31 may be replaced by a metal wall 31a having an array of small dielectric windows 25c therein, each covered by a correspondingly sized baffle 50c. A helical antenna 40f encircles the outside of the wall 31a, with high-efficiency, small conductor sections 45f aligning with the windows 25c and low-efficiency sections [[45f]] 46f aligning with the solid sections of the metal wall 31a between the window sections 25c. **Figs. 5A** and **5B** show alternative forms 40g, 40h, respectively, of the antenna 40f. Referring to **Figs. 5, 5A** and **5B**, such antennas 40f, 40g, 40h may be formed of a continuous conductor 43f,43g,43h, each having alternating high and

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low-efficiency sections, the high-efficiency, higher inductance sections 45f,45g,45h being formed of small cross-section conductors and the low-efficiency, lower inductance sections 46f,46g,46h being formed of large cross-section conductors. The apparatus in **Figs. 4A** and **5B** are shown with a solid bell jar-shaped window 31, as in **Fig. 1** **Fig. 1A**, in which case, rather than the individual shields 50c of **Fig. 5**, a cylindrical shield (not shown) would be provided with high-transparency sections aligned with the high-efficiency sections 45 of the antenna and low-transparency sections aligned with the low-efficiency sections 46 of the antennas 40.

Please replace paragraph [0089] with the following amended paragraph:

[0089] The antenna ~~[[50d]]~~ 40i also has one of the windings, namely winding 47a, in the divergent sections 46i of the antenna 40i, extending partially around to the top side of the dielectric window 31, beyond the extent of the baffle 50d. Such extended windings 47a have a small capacitive coupling with the plasma and, as a result, are effective in coupling energy to the plasma during plasma ignition.